Chapter 1

INTRODUCTION

1.1 OVERVIEW OF WIRELESS SENSOR NETWORK

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. Sensor in wireless network receives input information, store the information, compute and forward the data to other devices. For example, a thermocouple converts temperature to an output voltage which can be read by a voltmeter.

A Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance and is now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation, and traffic control [21].

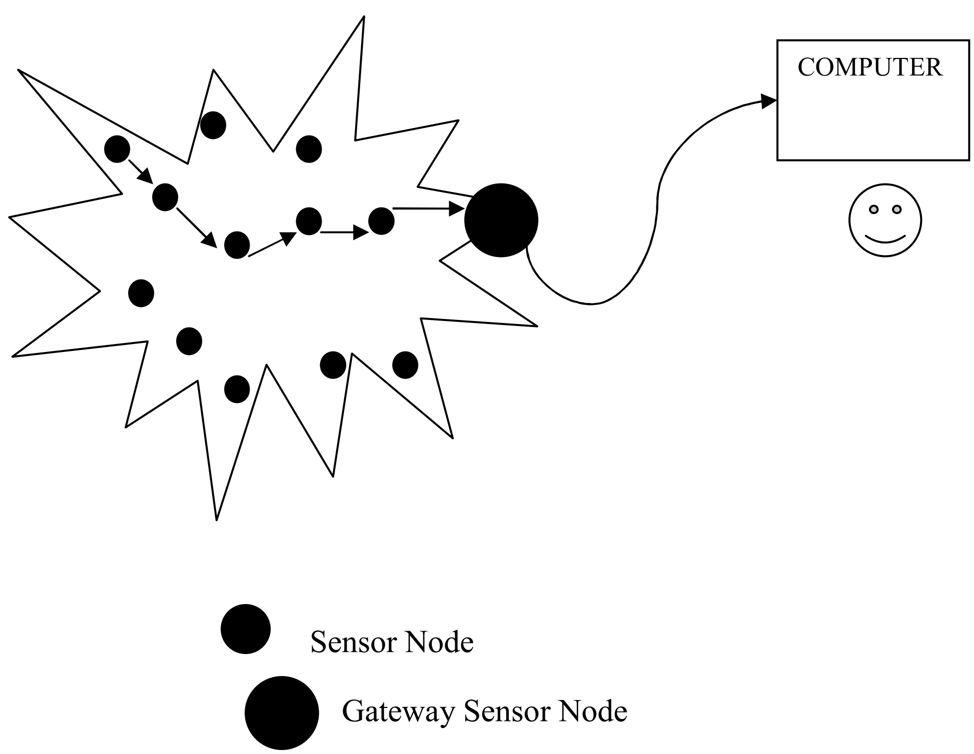

Figure 1.1: Typical multi-hop wireless sensor network architecture

In addition to one or more sensors, each node in a sensor network is typically equipped with a radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust.

The cost of sensor nodes is similarly variable, ranging from thousand rupees to a few pennies, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth.

A sensor network normally constitutes a wireless ad-hoc network, meaning that each sensor supports a multi-hop routing algorithm where nodes function as forwarders, relaying data packets to one of more "base stations".

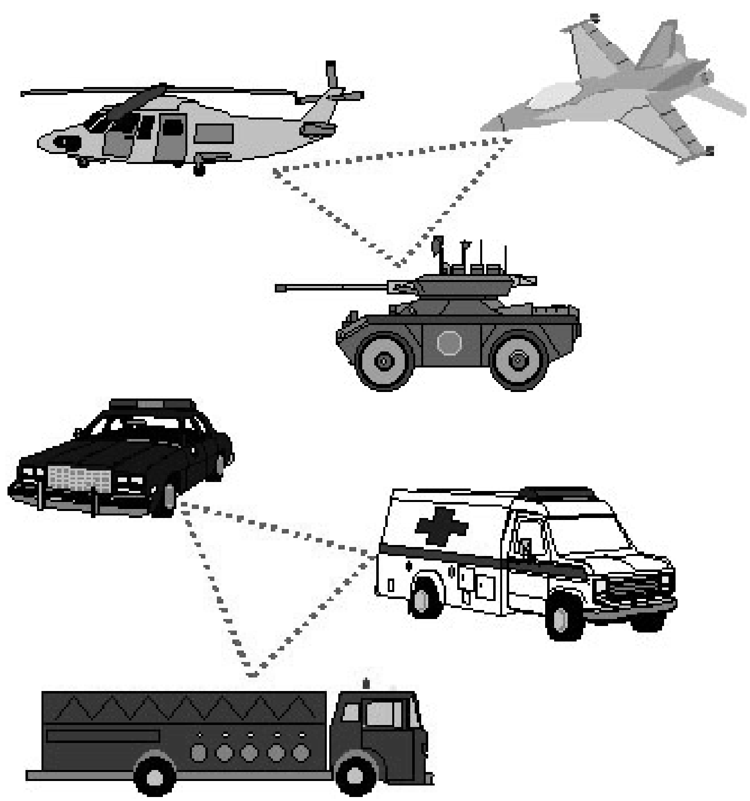

Figure 1.2: wireless ad-hoc sensor networks

A wireless ad hoc sensor network consists of a number of sensors spread across a geographical area. Each sensor has wireless communication capability and some level of intelligence for signal processing and networking of the data. In computer science and telecommunications, wireless sensor networks are an active research area with numerous workshops and conferences arranged each year.

1.2 WIRELESS SENSOR NEWORK APPLICATIONS

The applications for wireless sensor network are varied, typically involving some kind of monitoring, tracking, or controlling. Specific applications include habitat monitoring, object tracking, fire detection, land slide detection and traffic monitoring. In a typical application, a wireless sensor network is deployed in a region where it is meant to collect data through its sensor nodes.

1.2.1 Area monitoring

Area monitoring is a common application of wireless sensor networks. In area monitoring, the wireless sensor network is deployed over a region where some phenomenon is to be monitored. For example, a large quantity of sensor nodes could be deployed over a battlefield to detect enemy intrusion [21]. When the sensors detect the event being monitored (heat, pressure, sound, light, electro-magnetic field, vibration, etc.), the event is reported to one of the base stations, which then takes appropriate action (e.g., send a message on the internet or to a satellite). Similarly, wireless sensor networks can use a range of sensors to detect the presence of vehicles ranging from motorcycles to train cars.

1.2.2 Environmental monitoring

A number of WSNs have been deployed for environmental monitoring. Many of these have been short lived, often due to the prototype nature of the projects. Examples of longer-lived deployments are glacier monitoring.

1.2.3 Greenhouse monitoring

Wireless sensor networks are also used to control the temperature and humidity levels inside commercial greenhouses. When the temperature and humidity drops below specific levels, the greenhouse manager must be notified via e-mail or cell phone text message, or host systems can trigger misting systems, open vents, turn on fans, or control a wide variety of system responses. Because some

wireless sensor networks are easy to install, they are also easy to move as the needs of the application change.

1.2.4 Landslide detection

A landslide detection system makes use of a wireless sensor network to detect the slight movements of soil and changes in various parameters that may occur before or during a landslide. And through the data gathered it may be possible to know the occurrence of landslides long before it actually happens**.**

1.2.5 Machine health monitoring

Wireless sensor networks have been developed for machinery condition-based maintenance (CBM) [21] as they offer significant cost savings and enable new functionalities. In wired systems, the installation of enough sensors is often limited by the cost of wiring, which runs between 5oo– 50000 rupees per feet. Previously inaccessible locations, rotating machinery, hazardous or restricted areas, and mobile assets can now be reached with wireless sensors. Often, companies use manual techniques to calibrate, measure, and maintain equipment. This labor-intensive method not only increases the cost of maintenance but also makes the system prone to human errors. Especially in US Navy shipboard systems, reduced manning levels make it imperative to install automated maintenance monitoring systems. Wireless sensor networks play an important role in providing this capability.

1.2.6 Water/Wastewater monitoring

There are many opportunities for using wireless sensor networks within the water/wastewater industries. Facilities not wired for power or data transmission can be monitored using industrial wireless I/O devices and sensors powered using solar panels or battery packs.

1.2.7 Landfill ground well level monitoring and pump counter

Wireless sensor networks can be used to measure and monitor the water levels within all ground wells in the landfill site and monitor leachate accumulation and removal. A wireless device and submersible pressure transmitter monitors the leachate level. The sensor information is wirelessly transmitted to a central data logging system to store the level data, perform calculations, or notify personnel when a service vehicle is needed at a specific well. It is typical for

leachate removal pumps to be installed with a totalizing counter mounted at the top of the well to monitor the pump cycles and to calculate the total volume of leachate removed from the well. For most current installations, this counter is read manually. Instead of manually collecting the pump count data, wireless devices can send data from the pumps back to a central control location to save time and eliminate errors. The control system uses this count information to determine when the pump is in operation, to calculate leachate extraction volume, and to schedule maintenance on the pump.

1.2.8 Water tower level monitoring

Water towers are used to add water and create water pressure to small communities or neighborhoods during peak use times to ensure water pressure is available to all users. Maintaining the water levels in these towers is important and requires constant monitoring and control. A wireless sensor network that includes submersible pressure sensors and float switches monitors the water levels in the tower and wirelessly transmits this data back to a control location. When tower water levels fall, pumps to move more water from the reservoir to the tower are turned on [21].

1.2.9 Agriculture

Using wireless sensor networks within the agricultural industry is increasingly common. Gravity fed water systems can be monitored using pressure transmitters to monitor water tank levels, pumps can be controlled using wireless I/O devices, and water use can be measured and wirelessly transmitted back to a central control center for billing. Irrigation automation enables more efficient water use and reduces waste.

1.2.10 Fleet monitoring

It is possible to put a mote with a GPS module on-board of each vehicle of a fleet. The mote gathers it's position via the GPS module, and reports its coordinates so that the location is tracked in real-time. The motes can be equipped with temperature sensors to avoid any disruption of the cold chain,

helping to ensure the safety of food, pharmaceutical and chemical shipments. In situations where there is not reliable GPS coverage, like inside buildings, garages and tunnels, using information from GSM cells is an alternative for to GPS localization. Wireless sensor networks mainly used in controlling and monitoring purposes. Various fields as we saw in above applications depend on wireless sensor network. Traffic control is one of the best examples.

1.3 CHARATERISTICS OF WIRELESS SENSOR NETWORK

With the coming availability of low cost, short range radios along with advances in wireless networking, it is expected that wireless ad hoc sensor networks will become commonly deployed. In these networks, each node may be equipped with a variety of sensors, such as acoustic, seismic, infrared, still/motion video camera, etc. These nodes may be organized in clusters such that a locally occurring event can be detected by most of, if not all, the nodes in a cluster. Each node may have sufficient processing power to make a decision, and it will be able to broadcast this decision to the other nodes in the cluster. One node may act as the cluster master, and it may also contain a longer range radio using a protocol such as Bluetooth**.** Unique characteristics of a WSN include:

- Limited power they can harvest or store
- Ability to withstand harsh environmental conditions
- Ability to cope with node failures
- Coping with mobility of nodes
- Communication failures
- Heterogeneity of nodes
- Large scale of deployment
- Network self-organization
- Unattended operation
- Node capacity is scalable, only limited by bandwidth of gateway node.

Sensor nodes can be imagined as small computers, extremely basic in terms of their interfaces and their components. They usually consist of a processing unit

with limited computational power and limited memory, sensors (including specific conditioning circuitry), a communication device (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery.

The base stations are one or more distinguished components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end user as they typically forward data from the WSN on to a server. Many are ARM-processor based due to that CPU's low power requirements and typically store-and-forward data when wide-area-networking is available. Many techniques are used to connect to the outside world including mobile phone networks, satellite phones, radio modems, high power Wi-Fi links etc.

1.3.1 Hardware

The main challenge is to produce low cost and tiny sensor nodes. With respect to these objectives, many current sensor nodes are prototypes. There are an increasing number of small companies producing wireless sensor network hardware and the commercial situation can be compared to home computing in the 1970s. Some of the existing sensor nodes are given below. Many of the nodes are still in the research and development stage, particularly their software. Also inherent to sensor network adoption is the availability of a very low power method for acquiring sensor data wirelessly. Low power integrated radio transceivers are beginning to appear in "System on chip" ("SoC") CPUs which dramatically reduce the system size.

1.3.2 Software

Energy is the scarcest resource of WSN nodes, and it determines the lifetime of wireless sensor networks. Wireless sensor networks are meant to be deployed in large numbers in various environments, including remote and hostile regions, with ad-hoc communications as key. For this reason, algorithms and protocols need to address the following issues:

• Lifetime maximization

• Robustness and fault tolerance

• Self-configuration

1.3.3 Some of the "hot" topics in WSN software research are

• Security

• Mobility (when sensor nodes or base stations are moving)

• Usability - human intereface for deployment and management, debugging and end-user control

• Middleware: the design of middle-level primitives between high level software and the systems

1.3.4 Operating systems

Operating systems for wireless sensor network nodes are typically less complex than general- purpose operating systems. They more strongly resemble embedded systems, for two reasons. First, wireless sensor networks are typically deployed with a particular application in mind, rather than as a general platform for installing new applications. Second, a need for low costs and long lifetimes on limited batteries leads most wireless sensor nodes to have low-power microcontrollers, rather than high-power processors: mechanisms such as virtual memory either unnecessary or too expensive to implement. Examples of Operating system are TinyOS, MANTIS, BTnut, LiteOS, and Nano-RK. Early versions of TinyOS required writing all code in event-driven nesC, versions 2.1 [21].

1.3.5 Algorithms

Wireless sensor network s are composed of a large number of sensor nodes, therefore, distributed algorithms are often targeted. WSNs are often energy-constrained, that is, energy is a scarce resource, and one of the most energy-expensive operations is data transmission and idle listening. For this reason, much algorithmic research in wireless sensor networks focuses on the study and

design of energy aware algorithms for saving energy by reducing the amount of data being transmitted. To this end, techniques often employed are data aggregation, power cycling and the use of topology control algorithms.

Another characteristic to take into account is that due to the constrained radio transmission range and the polynomial growth in the energy-cost of radio transmission with respect to the transmission distance, it is very unlikely that every node will reach the base station, so data transmission is usually multi-hop (from node to node, towards the base stations).

The algorithmic approach to modeling, simulating and analyzing WSNs differentiates itself from the protocol approach by the fact that the idealized mathematical models used are more general and easier to analyze. However, they are sometimes less realistic than the models used for protocol design, since an algorithmic approach often neglects timing issues, protocol overhead, the routing initiation phase and sometimes distributed implementation of the algorithms.

1.3.6 Simulators

Simulators of Wireless Sensor networks come in all shapes and sizes. These range from those based on NS2, NS3, OMNET++ and OPNET, Jemula802, etc. to others which are based on advanced programming paradigms such as Agent-based modeling.
There are network simulator platforms specifically designed to model and simulate Wireless Sensor Networks, like TOSSIM, which is a part of TinyOS and COOJA which is a part of Contiki. Traditional network simulators like ns-2 have also been used. A platform independent component based simulator with wireless sensor network framework, J-Sim ([2]) can also be used. In addition, there is a simulator focused on the evaluation of topology control protocols in WSNs called Atarraya. An extensive list of simulation tools for Wireless Sensor Networks can be found at the CRUISE WSN Simulation Tool Knowledgebase.
Based on the OMNeT++ network simulator architecture, Mobility Framework and Castalia can be used for simulation of wireless sensor networks.

1.4 LOCALIZATION PROBLEM IN WIRELESS SENSOR NETWORK

Localization in sensor networks can be defined as ``*identification of sensor node's position*''. For any wireless sensor network, the accuracy of its localization technique is highly desired.

Localization is the issue of locating the geometrical position of the sensor node in the network. Localization problem is an estimation of position of wireless sensor nodes and to coordinate with one another. Localization is a challenge which deals with wireless sensor nodes and it has been studied from many years. There are different solutions and they are evaluated according to cost, size and power consumption. Localization is important when there is an uncertainty of the exact location of some fixed or mobile devices. One example has been in the supervision of humidity and temperature in forests and/or fields, where thousands of sensors are deployed by a plane, giving the operator little or no possibility to influence the precise location of each node [2].

Therefore, the *network localization problem*—namely, the problem of determining the positions of nodes in a network—has attraction of many engineering field and have been researched for many years. The device whose location is to be estimated is called localization node, and the network entity with known location is called localization base station. Wireless sensor network consists of a large set of inexpensive sensor nodes with wireless communication interface. These sensor nodes have limited processing and computing resources. Thus, algorithms designed for wireless sensor networks need to be both memory and energy efficient. In most of the algorithms for wireless sensor network, it is assumed that the sensor nodes are aware of their locations and also about the locations of their nearby neighbors. Hence, localization is a major research area in wireless sensor networks.

Nodes can utilize a global positioning system, but this solution is typically very costly. Many researchers are focusing on designing different algorithm but paying less attention on range measurement inaccuracy Localization is usually carried out by measuring certain distance dependent parameters of wireless radio link between the localization node and different localization base stations.

The parameters can be measured at the localization node or at the localization base station. The traveling time of a signal between the localization node and localization base station can easily be calculated. The time is proportional to the distance of them and it can be used as parameter of localization. It is referred to as time of arrival. There are many different algorithms to resolve these challenged, like DV hop, mobile beacon and area of angle. Every algorithm has its own merits and demerits. Some algorithms are best for accuracy and some for low cost, but it is difficult to get low cost and high accuracy at the same time from a single algorithm.

There are two situations when this problem gets more critical; when there are too many nodes in network and when the environment is hazardous. No single method has yet been adapted for outdoor environments

Many services are provided to users on the basis of location in wireless sensor networks. The role of location is very important in the wireless sensor networks. To access the data location is very important as the data itself. Location is also important for the upcoming areas such as ubiquitous computing, mobile services, networks planning and sensor networks [8].

There are different location techniques in which the most promising is GPS. GPS works in outdoor environments, but it requires reception of satellite signals. GPS receivers are also very costly as compared to laptops and sensor nodes.

The widespread use of wireless networks in enterprise and commercial establishments has also improved. Wi-Fi is used as an underlying technology to estimate the location of the sensor nodes. Tags are used to store information in wireless sensor networks. The tags send updated location information to a central database, at the same time when the equipment is moved.

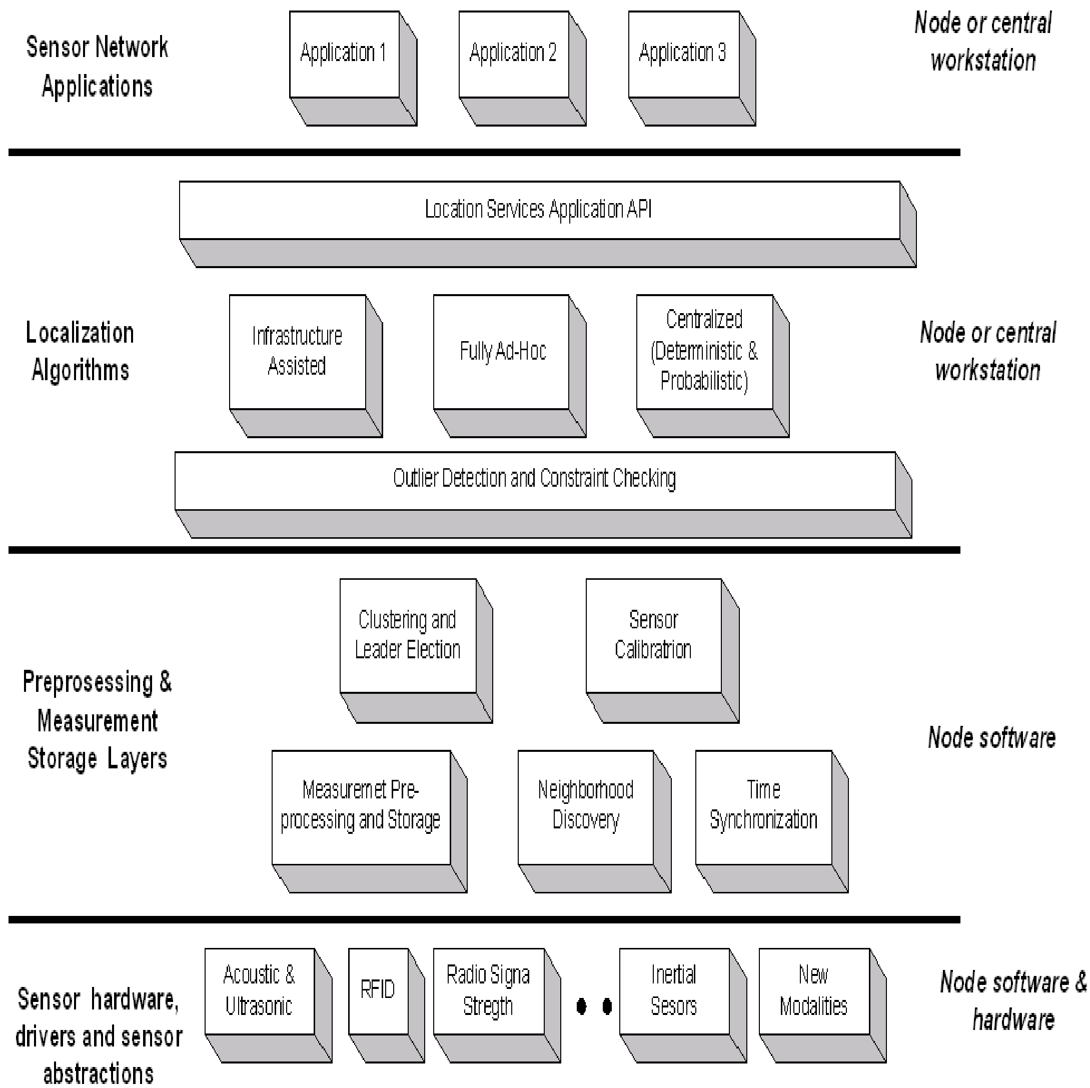

Figure 1.4: Localization service middleware

Another area where a user is granted access to network resources is location based access control such as database access based on the wireless user [8]. Localization is an integral part of most sensor networks where the data collected is mapped to its originating physical location. For example consider Zebra Net, a sensor network which is used to monitor the migration of zebras. Here the sensor nodes were strapped on zebras to take periodic measurement of their location and relevant biometric data [8].

Middleware is software that provides a link between separate software applications. Middleware is sometimes called plumbing because it connects two applications and passes data between them. Middleware allows data contained

in one database to be accessed through another. This definition would fit enterprise application integration and data integration software. Object web defines middleware as: "The software layer that lies between the operating system and applications on each side of a distributed computing system in a network.

Use of middleware:

Middleware services provide a more functional set of application programming interfaces to allow an application to:

- Locate transparently across the network, thus providing interaction with another service or application
- Filter data to make them friendly usable or public via anonymization process for privacy protection (for example)
- Be independent from network services
- Be reliable and always available
- Add complementary attributes like semantics

Localization service middleware we can see in figure 1.3.

1.5 APPROACHES TECHNIQUES IN WIRELESS SENSOR NETWORK

Existing location discovery approaches basically consists of two basic phases: (1) distance or angle estimation and (2) distance and angle combining. The most popular methods for estimating the distance between two nodes are described below:

1.5.1 Received Signal Strength Indicator (RSSI)

Received signal strength indicator (RSSI) is a measurement of the power present in a received radio signal. RSSI is generic radio receiver technology metric, which is usually invisible to the user of the device containing the

receiver, but is directly known to users of wireless networking of IEEE 802.11 protocol family. RSSI measures the power of the signal at the receiver and based on the known transmit power, the effective propagation loss can be calculated. RSSI is often done in the intermediate frequency (IF) stage before the IF amplifier. In zero-IF systems, it is done in the baseband signal chain, before the base band amplifier. RSSI output is often a DC analog level. It can also be sampled by an internal ADC and the resulting codes available directly or via peripheral or internal processor bus, next by using theoretical and empirical models we can translate this loss into a distance estimate. This method has been used mainly for RF signals. RSSI is a relatively cheap solution without any extra devices, as all sensor nodes are likely to have radios. The performance, however, is not as good as other ranging techniques due to the multi path propagation of radio signals. In [26], the authors characterize the limits of a variety of approaches to indoor localization using signal strengths from 802.11 routers. They also suggest that adding additional hardware or altering the model of the environment is the only alternative to improve the localization performance.

1.5.2 Time based methods (ToA, TDoA)

These methods record the time-of-arrival (ToA) or time-difference-of-arrival (TDoA). The propagation time can be directly translated into distance, based on the known signal propagation speed. These methods can be applied to many different signals, such as RF, acoustic, infrared and ultrasound. TDoA methods are impressively accurate under line-of-sight conditions. But this line-of-sight condition is difficult to meet in some environments. Furthermore, the speed of sound in air varies with air temperature and humidity, which introduce inaccuracy into distance estimation. Acoustic signals also show multi-path propagation effects that may impact the accuracy of signal detection.

1.5.3 Angle-of-Arrival (AoA)

Angle of arrival is a method for determining the direction of propagation of a radio frequency wave incident on an antenna array. AoA estimates the angle at which signals are received and use simple geometric relationships to calculate

node positions. Generally, AoA techniques provide more accurate localization result than RSSI based techniques but the cost of hardware of very high in AoA. For the combining phase, the most popular alternatives are:

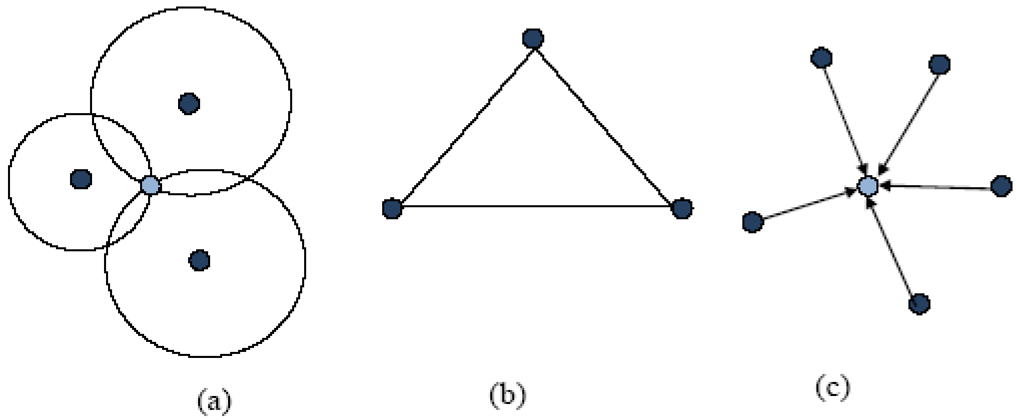

Figure 1.5: Localization techniques (a) Hyperbolic trilateration (b) Triangulation (c) Maximum Likelihood Estimation

1.5.4 Hyperbolic Trilateration:

The most basic and intuitive method is called hyperbolic trilateration. It locates a node by calculating the intersection of 3 circles as shown in Fig. 1.5(a).

1.5.5 Triangulation:

This method is used when the direction of the node instead of the distance is estimated, as in AoA systems. The node positions are calculated in this case by using the trigonometry laws of sines and cosines (shown in Fig. 1.5(b)).

1.5.6 Maximum Likelihood (ML) estimation:

ML estimation estimates the position of a node by minimizing the differences between the measured distances and estimated distances shown in Fig. 1.5(c).

1.6 LOCALIZATION AREA OF DEPLOYMENT

There are different localization schemes for wireless networks of different deployment area. This is because of the difference in network topology, number of users, and available resources for such networks. The localization can be classified in to three types depending on the deployment area and type of wireless sensor network.

1.6.1 Wide area localization

This technique is used for outdoor deployment. Wide area localization is long range localization and there is problem of power but it is also a more expensive, used in cellular network. Global positioning system (GPS) can be used for this purpose most of the time, but sometime cellular network infrastructure also be used.

Localization can be performed from reading at least three base stations. Local base transceivers are base stations and cellular phone is local network. In indoor environment it is difficult to maintain accuracy. We mostly use time of arrival technique in cellular network for localization.

1.6.2 Local Area Localization

Local area localization is used for indoor implementation. The size of localization area is very small due to that it is very cheap. Wireless access points work as local base station while devices such as laptops and personal handheld devices work as local network. GPS can not be used in indoor environment. We use received signal strength (RSSI) technique to solve localization problem. This technique is based on distance varying parameter so it is not robust in complex, environment due to multipath and movement of people environment.

1.6.3 Ad – hoc Localization

Ad-hoc network is heterogeneous and more power constrained. There is need of some algorithms for this kind of network. The consumption is very low and low cost can be obtained for communication. The nodes can be located with respect

to location of reference nodes, also known as anchors node which could be movable or static in wireless sensor network.

1.7 COMPUTATIONAL MODEL FOR NETWORK MANAGEMENT

Research on localization in wireless sensor networks can be classified into two broad categories. Each approach may be appropriate for a different application, Centralized approaches require routing and leader election, fully distributed approach does not have this requirement.

(a) **(b)**

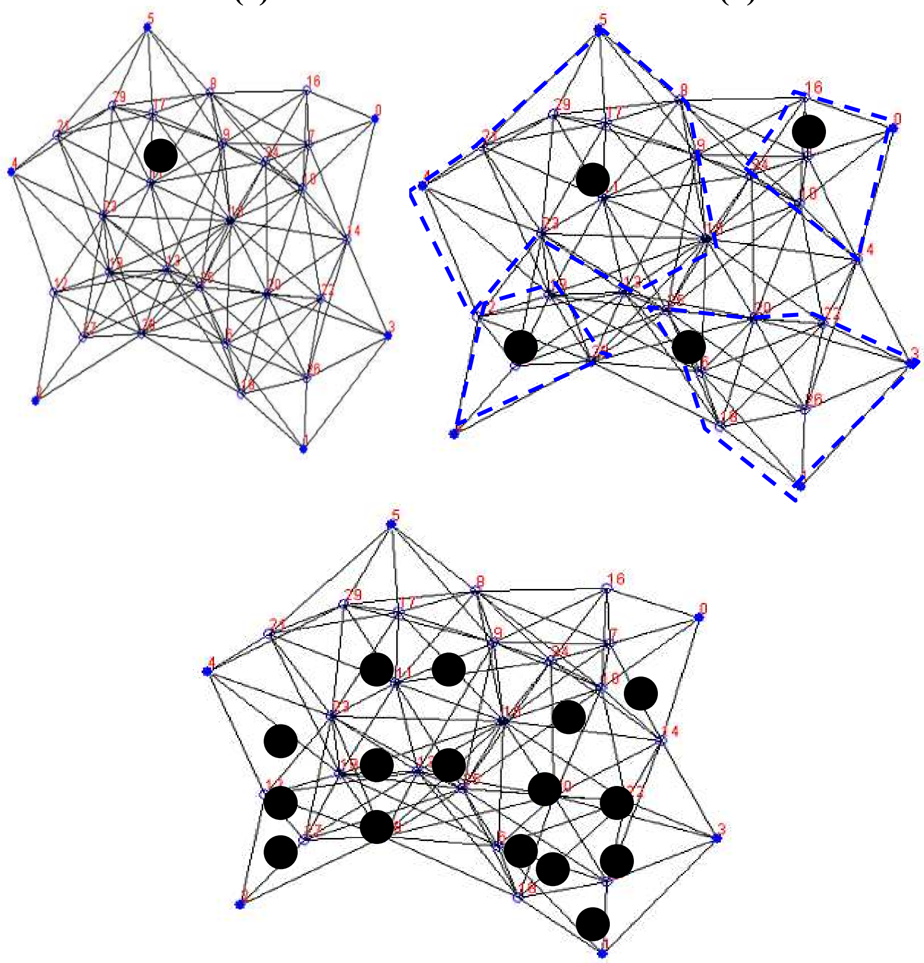

Figure 1.7: Computational model (a) centralized approach (b) locally centralized approach (c) distributed approach

1.7.1 Centralized Localization:

Centralized localization is basically migration of inter-node ranging and connectivity data to a sufficiently powerful central base station and then the migration of resulting locations back to respective nodes. The advantage of centralized algorithms are that it eliminates the problem of computation in each node, at the same time the limitations lie in the communication cost of moving data back to the base station. As representative proposals in this category [5, 6, 7] are explained in greater detail.

1.7.2 Distributed Localization:

In Distributed localizations all the relevant computations are done on the sensor nodes themselves and the nodes communicate with each other to get their positions in a network. In this approach required much computation for processing the data. Each node works as a computing station, store the data and forward the data to other nodes. The cost of this mechanism is high because each station works as a computing station.

1.7.3 Locally centralized approach: This approach is based on cluster method where in each cluster a node works as a master or base station for that cluster and compute the information for other nodes figure 1.b. In this approach we can do the computation locally and forward the data to the main base station controller. This approach gives the high performance as the computation is done locally and required less computing in comparisons of distributed and centralized approach.

1.8 CLASSIFICATION OF APPROACHES IN WIRELESS SENSOR NETWORK

Localization is classified mainly three categories according to the computation in wireless sensor network as specified above and in figure also. Further each category divided in to corresponding methods to solve localization problem.

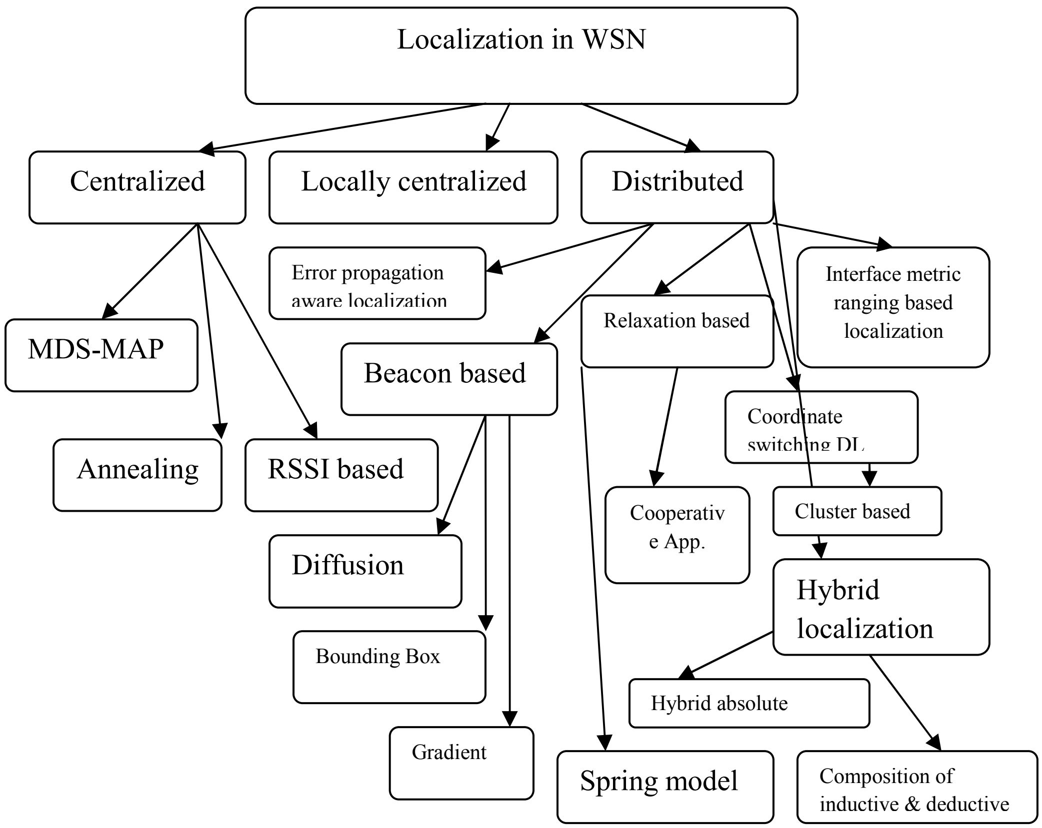

Figure 1.8: classifications of localization approaches in wireless sensor networks

1.9 ISSUES AND CHALLENGES IN LOCATION DISCOVERY

1.9.1 Current Issues:

1.9.1.1- Resource constraints: nodes must be cheap to fabricate, and trivially easy to deploy. Nodes must be cheap, since fifty cents of additional cost per node translates to $500 for a one thousand node network. Deployment must be easy as well: thirty seconds of handling time per node to prepare for localization

translates to over eight man-hours of work to deploy a 1000 node network. That means designers must actively work to minimize the power cost, hardware cost, and deployment cost of their localization algorithms.

1.9.1.2- Node density: Many localization algorithms are sensitive to node density. For instance, hop count based schemes generally require high node density so that the hop count approximation for distance is accurate . Similarly, algorithms that depend on beacon nodes fail when the beacon density is not high enough in a particular region. Thus, when designing or analyzing an algorithm, it is important to notice the algorithm's implicit density assumptions, since high node density can sometimes be expensive if not totally infeasible

1.9.1.3- Environmental obstacles and terrain irregularities: Environmental obstacles and terrain irregularities can also wreak havoc on localization. Large rocks can occlude line of sight, preventing TDoA ranging, or interfere with radios, introducing error into RSSI ranges and producing incorrect hop count ranges. Indoors, natural features like walls can impede measurements as well. All of these issues are likely to come up in real deployments, so localization systems should be able to cope.

1.9.1.4- Security: Security is the main issue in localization as the data is transferred from beacon node to anchor node then any of mobile beacons which is a virus or not secure acting as original mobile beacons transmit false messages due to this an error will occur which is harmful for our computation.

1.9.1.5- Non convex topologies: Border nodes are a problem because less information is available about them and that information is of lower quality. This problem is exacerbated when a sensor network has a non-convex shape: Sensors outside the main convex body of the network can often prove unlocalizable. Even when locations can be found, the results tend to feature disproportionate error.

1.9.2 Future challenges in location discovery approaches:

Research on localization in wireless sensor networks can be classified into two broad categories centralized and distributed. These algorithms are given by researchers but there are some aspects which we will consider as a challenge in future.

1.9.2.1 Distributed Localization: If each node collects partial data and executes the algorithm then localization algorithm is distributed.

1.9.2.1.1 Beacon-based distributed algorithms: Categorized into three parts:

- *Diffusion*: In diffusion the most likely position of the node is at the centroid [22] of its neighboring known nodes. APIT requires a high ratio of beacons to nodes and longer range beacons to get a good position estimate. For low beacon density this scheme will not give accurate results.
- *Bounding box*: Bounding box forms a bounding region for each node and then tries to refine their positions. The collaborative multilateration enables sensor nodes to accurately estimate their locations by using known beacon locations that are several hops away and distance measurements to neighboring nodes. At the same time it increases the computational cost also.
- *Gradient:* Error in hop count distance matrices in the presence of an obstacle.

1.9.2.1.2- Relaxation-based distributed algorithms:

The limitation of this approach is that the algorithm is susceptible to local minima [5].

1.9.2.1.3- Coordinate system stitching based distributed algorithms:

The advantage of this approach is that no global resources or communications are needed. The disadvantage is that convergence may take some time and that nodes with high mobility may be hard to cover.

1.9.2.1.4- Hybrid localization algorithms:

The limitation of this scheme is that it does not perform well when there are only few anchors. SHARP gives poor performance for anisotropic network.

1.9.2.1.5- Interferometric ranging based localization:

Localization using this scheme requires considerably larger set of measurement which limits their solution to smaller network.

1.9.2.2 Centralized Localization:

If an algorithm collects localization related data from one station and execute it from the same station then it is called centralized. In centralized model the problem is that if computing server fails due to some problem then entire processing goes down. Scalability is another problem when we consider the centralized model for computation of our data. For security reasons this approach is also not best. The techniques which are based on centralized model are explained below.

- **MDS-MAP:**

The advantage of this scheme is that it does not need anchor or beacon nodes to start with. It builds a relative map of the nodes even without anchor nodes and next with three or more anchor nodes, the relative map is transformed into absolute coordinates. This method works well in situations with low ratios of anchor nodes. A drawback of MDS-MAP [10] is that it requires global information of the network and centralized computation.

- **Localize node based on Simulated Annealing:**

This algorithm does not propagate error in localization. The proposed flip ambiguity mitigation method is based on neighborhood information of nodes and it works well in a sensor network with medium to high node density. However when the node density is low, it is possible that a node is flipped and

still maintains the correct neighborhood. In this situation, the proposed algorithm fails to identify the flipped node

- **A RSSI-based centralized localization technique:**

The advantage of this scheme is that it is a practical, self-organizing scheme that allows addressing any outdoor environments [8]. The limitation of this scheme is that the scheme is power consuming because it requires extensive generation and need to forward much information to the central unit.

1.9.2.3 Locally centralized approach:

This approach is combination of both centralized and distributed approach. It has the advantage of both the approaches. It follows the cluster approach. Problem is that the system become more complex and need more computation for handling the network.

1.10 PROBLEM DEFINITION

There are many localization schemes for the localization of wireless sensor network. Since each algorithm was developed to fulfill a different goal, they vary widely in many parameters including accuracy, cost, size, configurability, security, and reliability [9, 10]. The node localization problem for wireless sensor networks has received considerable attention, driven by the need to obtain higher location accuracy without incurring a large per-node cost (monetary cost, power consumption and form factor). Despite the exports made, no system has emerged as a robust, practical, solution for the node localization problem in realistic, complex, outdoor environments [11]. One such challenge is how to accurately find the location of each sensor node, at a low cost. The node localization problem has received tremendous attention from the research community, thus emphasizing that it is an important problem and it’s hard to resolve this problem. Despite the attention the localization problem for wireless sensor networks has received no universally acceptable solution for realistic, outdoor, environments. There are many problems regarding the localization but accuracy and cost are more concerned.

1.10.1 Accuracy: Accuracy is very important in the localization of wireless sensor network. Higher accuracy is typically required in military installations, such as sensor network deployed for intrusion detection. However, for commercial networks which may use localization to send advertisements from neighboring shops, the required accuracy may not be lower.

1.10.2 Cost: Cost is a very challenging issue in the localization of wireless sensor network. There are very few algorithms which give low cost but those algorithms don't give the high rate of accuracy.

1.10.3 Power: Power is necessary for computation purpose. Power play a major role in wireless sensor network as each sensor device has limited power. Power supplied by battery.

1.10.4 Static Nodes: All static sensor nodes are homogeneous in nature. This means that, all the nodes have identical sensing ability, computational ability, and the ability to communicate. We also assume that, the initial battery powers of the nodes are identical at deployment.

1.10.5 Mobile Nodes: It is assumed that a few number of GPS enabled mobile nodes are part of the sensor network. These nodes are homogeneous in nature. But, are assumed to have more battery power as compared to the static nodes and do not drain out completely during the localization process. The communication range of mobile sensor nodes are assumed not to change drastically during the entire localization algorithm runtime and also not to change significantly with in the reception of four beacon messages by a particular static node.

The following issues will be addressed in this thesis.

- How to develop a localization algorithm fulfilling the tight bounds of resources.
- How to get high accuracy and shortest path to solve localization problem in wireless sensor network.
- How to approach the universal use of a single algorithm.

The goal of this thesis is to provide a good solution for localization problems in the wireless sensor networks with high accuracy and low cost which comes when the mobile beacon moves the shortest path in deployment area. The focus will mainly be on accuracy in the localization of wireless sensor network as well as low cost. Some existing algorithms for localization will be analyzed and propose a new approach that can be used in more situations. Many of the existing algorithms will be evaluated to understand the problem. A survey of existing algorithms for localization in wireless sensor networks will be made, and be used as a basis to design an algorithm that can be used in many situations.

In next chapter 2 we present related work in wireless sensor network. A lot of research has been done in this area and much more is still needed because of cost, power and accuracy are the constraints, where we need to improve. We propose an approach which works in both, range free and range based technique to improve all the constraints. In chapter 3 we present our proposed work which is enhancement of previous composite approach. We propose an algorithm with mobile beacon shortest path to solve localization problem in wireless sensor network, we combined the proposed work with DV-hop method, called Enhanced composite approach. This is unique approach which follow both range based and range free techniques in wireless sensor network. In chapter 4 we have presented and compared the simulation results of enhanced composite approach with mobile beacon method, DV-hop method and previous composite approach. In chapter 5 we present conclusion and future scope of this enhanced composite approach.

Chapter 2
ALGORITHMS FOR LOCALIZATION

The existing algorithm for localization can be broadly classified into two basic categories:

1. Range based techniques and Range Free Techniques.

In range based mechanisms, the location of a sensor node can be determined with the help of the distance or angle metrics. These metrics are Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of Arrival (AoA), Received Signal Strength Indicator (RSSI). Range based techniques are highly accurate but, they are equipped with highly expensive hardware and requires a lot of computation. It increases the cost of the network and is inefficient in terms of computations. The various range based techniques are Radio Interferometric Measurement (RIM) [3], Multidimensional Scaling (MDS) [11], 3D - Landscape [14], DV-distance, DV-hop, Euclidean distance [15] etc. In range free techniques, the position of sensor node is identified on the basis information transmitted by nearby anchor nodes or neighboring nodes, based on hop or on triangulation basis. The various range free techniques are APIT [22], chord selection approach [2], three dimensional multilateration approach [5], SerLOC [6], centroid scheme [7] etc. Many more techniques are discussed in [4, 8, 13, 15, 17, 18] . The range free techniques have an error in accuracy up to 10% of the communication range of individual node [2]. But, these techniques are much cheaper than the range based techniques.

In [2], Ou and Ssu have proposed a range free localization approach for three dimensional wireless sensor networks. In this approach a GPS equipped flying anchor is moved around a region under surveillance and it continuously broadcasts its position information. These messages help other sensor nodes to compute their location. This scheme was proved to be better than any existing range free localization scheme for three dimensional wireless sensor networks. The basic assumption in this work is that the nodes are static. Thus, for every run of the algorithm the flying anchor will be required to fly in the network. As,

the flying anchor node is not a participating node in the WSN, it is impractical to be used in case of applications where sensors are more prone to displacements. In such applications, the network needs to have the ability to self-localize, whenever required. For this purpose, we need have few GPS enabled sensor nodes within the region to be monitored. These nodes will help other nodes to determine their location based on the positional information about themselves. Further, in case of any discrepancy, the sensor nodes may send an error message to base station regarding its dislocation. The base station will generate a query message to other stations.

The Global positioning system (GPS) enabled sensor nodes will broadcast their locations. With the help of this location information, the displaced node can compute its new location. The above discussed strategy can be achieved by two schemes:

1. Enable a few static sensor nodes in the network with GPS equipped devices. These nodes will help in locating their neighbors depending on the placement strategy. The rest of sensor nodes will collectively get localized with the help of their respective neighboring nodes.
2. Take a few GPS enabled mobile sensor nodes to move within the network and help in locating the other sensor nodes.

The main drawback in using static sensor nodes is that, these nodes get their location computed with the help of locations of their neighboring nodes as proposed in [5]. If there is an error while computing the nodes location, this error gets rippled in computations related to next tiers of neighbors and so on. Hence, the anchor nodes which are the most vital part of the localizing scheme must be a part of the network and preferable mobile in nature.

Here we will discuss some existing algorithms and techniques which are used to solve localization problem in wireless sensor network. Each algorithm has some merits and demerits, play important role as per the application requirement. We discuss here only two type of algorithm DV-hop and mobile beacon.

Localization with high accuracy and low cost in wireless sensor network is still under exploration. Only a few researchers have tried to address the problem using both range based and range free techniques. S.Rao [20] addressed a scheme "A Composite approach to deal with localization problem in wireless sensor network". In this technique combined two approaches (A) DV- Hop and (B) Mobile beacon.

A. DV-HOP ALGORITHM FOR LOCALIZATION

DV- hop algorithm composed of 3 steps.

1. Information of position at each node.
2. Estimation of distance for one hop.
3. Estimation of position.

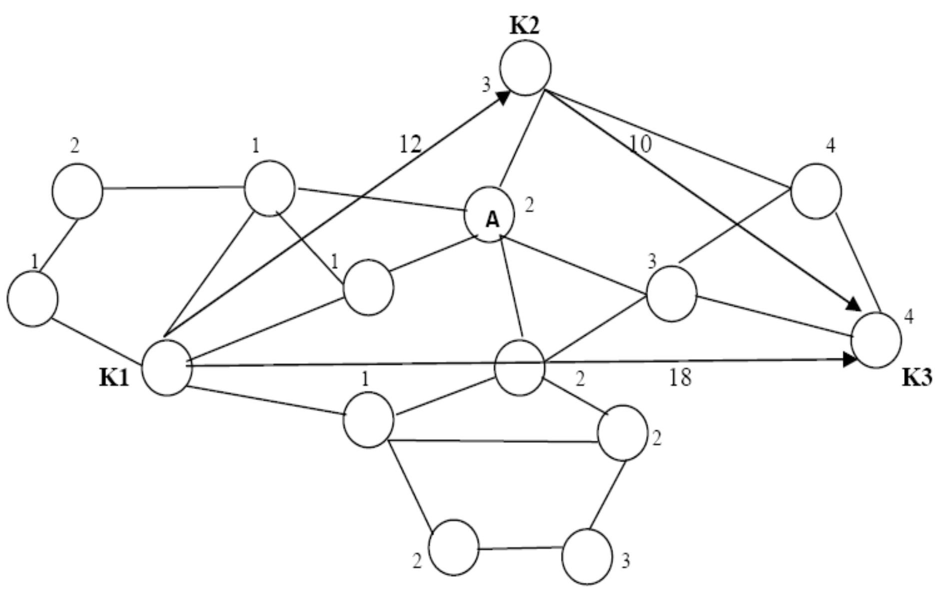

Figure 2.1: DV-HOP analysis diagram.

The first step of the algorithm is the flooding of the position of sources through the network. Each node and sources record their hop-distance with other sources in the network. Sources try to find out the average length of one node and this process is called hop correction [10]. The other nodes wait for the first correction.

It broadcast this information to the other nodes after accepting this. Now, the nodes do not need to wait any more and it directly goes to next step. In the last step, the nodes try to find out their position according to number of hops recorded for each source and to the hop correction.

Landmarks K1, K2, K3 are shown below in figures 2.1. Actual distance between landmarks is also mentioned. The landmarks calculate the average distance of each hop.

- *K1: (12+18)/ (3+4) =4.23.*
- *K2: (12+10)/ (3+2) = 4.40.*
- *K3: (10+18) / (2+4) = 4.67.*

The average distance can be used to correct the position. The node A is getting its direction from K2. The distance can be obtained as:

- *A-K1: 2*4.4=8.8.*
- *A-K2: 1*4.4=4.4.*
- *A-K3: 2*4.4=8.8.*

Accuracy of this algorithm varies with the accuracy of distance between the hops. The node A gets the direction from the given landmarks as in figure 2.1 but problem is that there are three different landmarks. So node A will get three coordinates which is more ambiguous because A will get three distances from its actual position in the mean time. The concept of beacon is used to solve this problem. More than three beacon nodes are needed to overcome this problem.

Accuracy of this algorithm is very low because the average distance per-hop is a rough estimation so it is difficult to find the accurate distance between the hops. This algorithm works properly when shapes are same or shapes are regular but it does not work for irregular shapes. This is the biggest drawback of this algorithm. There are many problems which need to be resolved. The solution of

these problems is available in the improved DV-Hop algorithm. DV-hop algorithm is invalid for irregular shapes. The accuracy level is very low, and it is difficult to find out the actual distance between the hops.

B. MOBILE BEACON ALGORITHM FOR LOCALIZATION

This method is an alternative for centralized approach. A node which locates itself is called Beacon node. A mobile beacon could be a human, machine, plane or any vehicle which is movable in deployment area. Trajectory is a path followed by moving beacon in the deployment area. This algorithm is expensive because of GPS system. Both DV-hop and mobile beacon approaches have its own merits and demerits. S.Rao [20] combined both approaches and designs a composite approach which is a bit better than other two methods.

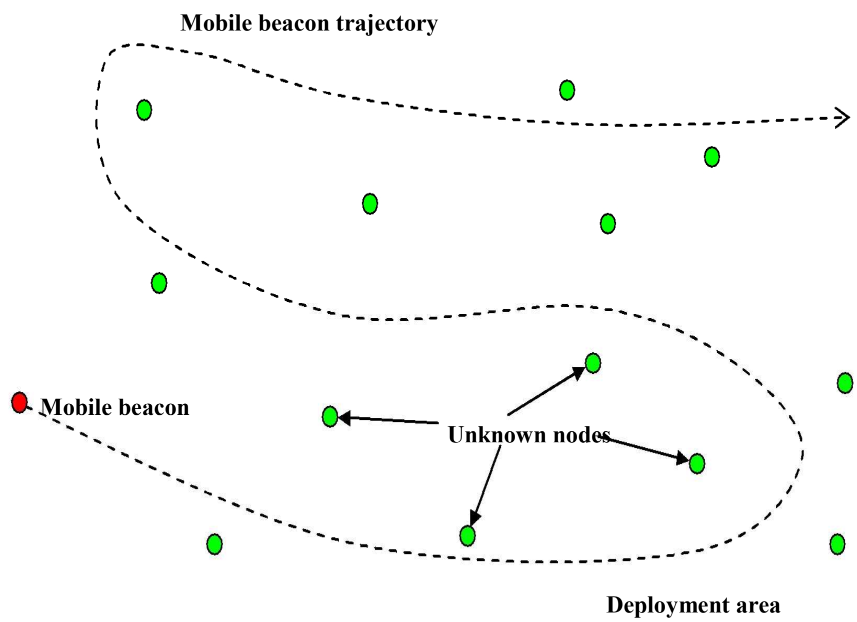

Figure 2.2: mobile beacon trajectories

In mobile beacon approach a mobile beacon traverse the area randomly where sensors are deployed. Using trilateration method some blind node estimate its position. But as traverse path has no routing algorithm that's why power consumption is maximum.

Chapter 3

PROPOSED WORK

3.1 PROPOSED MOBILE BEACON ALGORITHM USING SHORTEST PATH

Several types of mobile elements capable of free movement are currently available, e.g., Packbot [11] and Robomote [12]. In practice, the mobile element cannot visit some positions due to physical obstacles. We assume that the locations which are not traversable are known. To achieve the shortest path we partitioned the deployment area into hexagon cells which is visit able location. We only consider the minimal set of hexagons that cover the visit able region. Due to power constraints, the mobile element is capable of only low-speed and short-distance movement in practical deployments. For instance, the normal speed of several mobile sensor platforms (e.g., Packbot and XYZ) is only 0.5 ~ 2 *m/s*. An ABC mobile sensor node that is powered by two batteries can move only about 165 meters before exhausting its power. Therefore, the movement trace of the mobile beacon in deployment area must be efficiently planned or controlled in order to maximize the number of localized unknown-position sensors with the required high localization accuracy. Mobile beacon traverse from the center point of each hexagon cell in deployment area and continuously broadcast its position message using this information all blind nodes estimate its position [13]. The mobile beacon assists the unknown nodes in localizing themselves after the sensor node has been deployed [14]. It could be a human, machine, a plane or other vehicles. The optimal movement schedule for mobile beacon in our algorithm needs to achieve the shortest path length so that the mobile beacon covers the entire area with the shortest time and consumes the minimum energy. Based on the derived localization error bound, we propose an optimal movement schedule for mobile beacon as follows: When the mobile beacon has no prior information about sensors' positions, in order to guarantee that each sensor is localized with error e, the entire geographical region should be covered by disks with radii r centered at the beacon points of the mobile beacon.

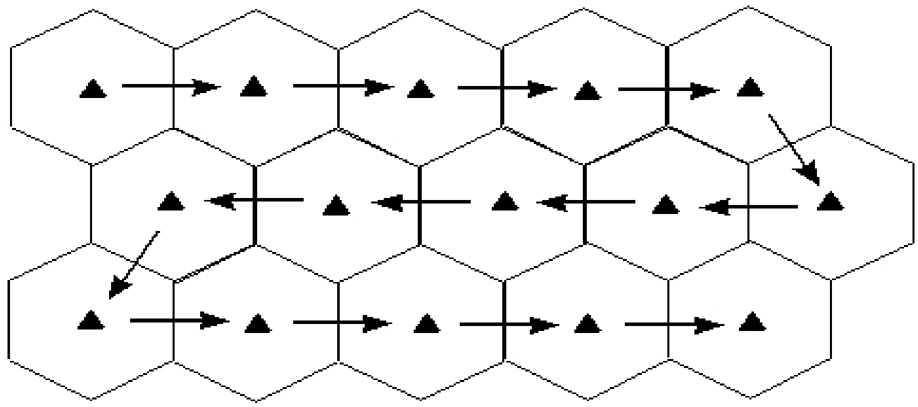

Figure 3.1: Enhanced mobile beacon trajectory

The most efficient coverage is the hexagonal tiling of the entire region, in which the edge length of each hexagon is r and each beacon point is at the center of each hexagon. In the optimal movement schedule of the mobile beacon, the center of a hexagon is visited by the mobile beacon once. Obviously, the shortest length of a path that crosses a hexagon is $\sqrt{3}r$. In the line by line scan as shown in Figure 3.1, the shortest path length is achieved. Therefore, the line-by-line scan is an optimal movement schedule of the mobile beacon. When each sensor has coarse prior information about its position, the mobile beacon does not need to cover the entire region. Suppose there are *N* sensors and sensor *i is* in region *Ai* with high probability. Let *{Hi}* denote the minimal set of hexagons that covers the united regions Ui=1 to N *Ai*, where *Hi* is one of the hexagons in the hexagonal tilings of the entire geographical region. Note that *{Hi}* can be found by checking whether each hexagon has intersection with Ui=1 to N *Ai*,, and hence in polynomial time. Construct an unidirectional graph *G* = (*V, E*), where *V* is the set of centers of *{Hi}* and *E* is the set of Euclidean distances between any two points in *V*.

The movement schedule of the mobile beacon can be formulated as the shortest Hamiltonian path problem. Specifically, given a starting point that is a vertex in *V*, find the shortest path that visits each vertex in *V* exactly once. We note that the problem of finding a Hamiltonian path is NP-complete and therefore the problem of finding the shortest Hamiltonian path is also NP-complete [18]. This

algorithm is expensive because of using GPS. It is difficult to find the location of all the nodes in mobile beacon algorithm. The optimal movement schedule of the mobile anchor when no information about sensors' positions is available. The triangles represent the way points of the mobile anchor. The edge length of each hexagon is r.

Finally the mobile beacon with global positioning system covers the shortest path as it moves according to the algorithm, from middle of each hexagon cells. Due to these hexagon cells the coverage error also reduces because there is no such area where a range can not reach or no overlapping area. Require only one GPS and covers shortest path which makes this approach cost saver as compared to other approaches.

[3.2] PROPOSED ENHANCED COMPOSITE APPROACH

Each range free and range based techniques has some drawback, problem, merits and demerits. To resolve all the problems Enhanced composite approach is proposed, which is the enhancement of earlier composite approach. The main aim of this proposed work in this given thesis is to solve localization problem with high accuracy, low cost and use of minimum battery power.

The position of sensor node is identified by combining both range based and range free techniques to reduce the positioning error with improved performance and efficiency.

In this approach we combined the DV-hop method and proposed mobile beacon algorithm using shortest path, to give the high accuracy in localization with minimum cost in wireless sensor network. This enhanced composite approach has basically three steps. First, mobile beacon traverses the center position of each hexagon cell and periodically broadcast the message with its position information. Using this information some blind nodes which are in the range of broadcasting, estimate its position using trilateration method. In trilateration method it is must that blind node received more than three packets continuously broadcast by mobile beacon for estimation of accurate position.

In step two, during mobile beacon movement some blind node locates themselves as a static node then they play as a landmark role in DV-hop method.

In third step, static beacon as a landmark when they are out of range of the mobile beacon because till the mobile beacon in the range they cannot calculate the hop distances. We need a threshold value to answer “when static node become landmark in DV-hop”. Threshold value is the number of static node. When the number of static nodes reaches the threshold value, all static nodes become landmarks. Another method is when mobile beacon traversing for a circle. In this way as mobile beacon moves, they can generate new static beacons to provide the position information by using trilateration method and after that when mobile beacon then out of range then using DV-hop method rest of the blind node estimate its position. When blind node locates itself it becomes beacon node for other blind nodes. So it spreads in the way like the wave from the center to the outer region. The flow chart of this proposed composite approach figure 4.1 includes above described three steps.

The proposed algorithm is designed to sole the problems existing in DV-hop method. The main improvement is when the mobile beacon broadcast the position information while traversing in the deployment region which is divided in to hexagon cells and passing at the middle by using any shortest path technique. When mobile beacon moves it generates new static beacons using trilateration method. The accumulation and exaggeration of the errors in the DV-hop will not be the part of this method.

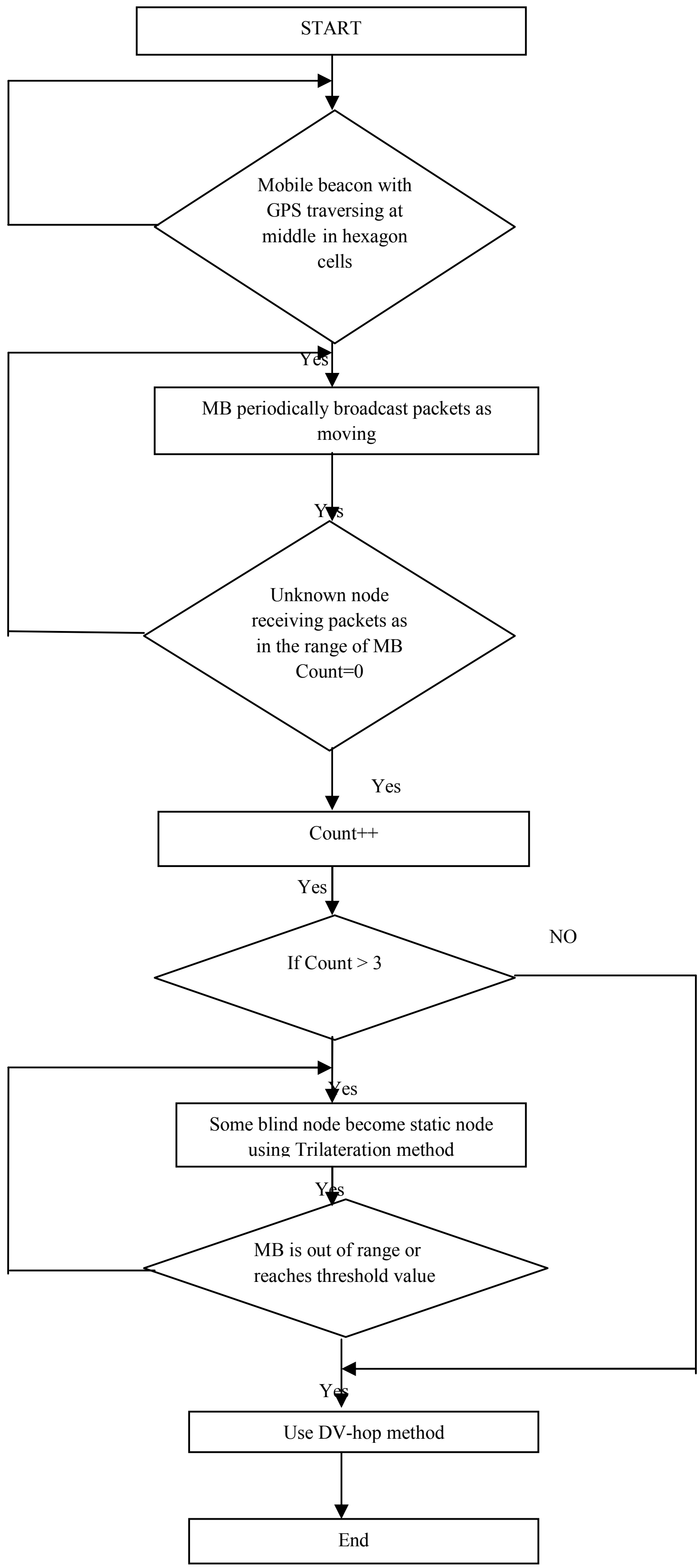

Figure 3.2: Flow Chart for Enhanced composite approach

Second DV-hop works well in the isotropic network. Even though the network will be anisotropic, when using the enhanced composite approach and the changing of topology is not required, because simply change the trajectory of the mobile beacon solve the problem in simple way.

Third this algorithm is the incorporation of the range based and range free so the measurement errors can be calibrated by the agitated DV-hop method. This algorithm increases the flexibility to introduce a threshold value to control the change agitating the DV-hop method.

The entire working of algorithm we can see in the figure 4.1, flow chart of enhanced composite approach with mobile beacon shortest path to solve localization problem in wireless sensor network. Mobile beacon with global positioning system enabled device moves from the center of each hexagon cells if yes then it broadcast the beacon message otherwise again start traversing from initialization point. Unknown node starts receiving message from mobile beacon as they are in the range of mobile beacon. There also runs a counter on static node side, which count the number of message received by each blind node. If counter value greater than three it means localization problem solved by trilateration method and after we use DV hop method to localize other blind nodes. If counter value less than three than uses DV-hop method only.

Chapter 4
EVALUATION

The evaluation defines an inspection simulation experiment where our algorithm will be evaluated and some important performances will be estimated. The purpose of the evaluation is to create a virtual environment which imitates the real environment to conduct the experiment. In this environment, the proposed algorithm is evaluated and performance is compared to the DV-hop method. The evaluation is running using MATLAB. The data is collected from repeated simulations. The first step studies the DV-hop wireless sensor network. In the second step, the proposed method is evaluated under the same settings. A performance comparison is then made between the algorithm implemented and the traditional DV-Hop method to the simulation result. There are two main attributes to evaluate; average position error, and average communication traffic. In the simulations, the unknown nodes are deployed randomly in a region of 100 by 100 units. The mobile beacon traverses the sensor network along the routine for the sake of precision and simplicity while broadcasting beacon packets. Obviously, this trajectory is always optimal, so it is at good enough to cover the simulation and get the anticipated results.

4.1 DV-hop simulation

The distributed unknown nodes are 20 in the given simulation environment. Choose the number of randomly deployed beacons as the independent variable and its range is from 3 to 10. Then simulation result of DV-hop is shown. Table 4.1 illustrates that the nodes' position computed out through DV-hop method have deviated from the actual position value completely. Meanwhile, it also shows that more beacons do not mean the more accuracy. Because of the random deployment of the beacons, the result values are different in each simulation. However, it can disclose the drawback of the traditional DV-hop algorithm, depending on the topology and the error of the correction value used to calibrating the distance for one hop.

Table 4.1 Average position errors and traffic of DV-hop

No. of beacons	Average traffic	Error Intervals
3	18.87	3.0724
4	26.29	1.6703
5	32.52	1.5776
6	41.00	0.6304
7	50.70	0.7688
8	55.57	0.7015
9	62.07	1.1222
10	70.60	1.1381

4.2 Mobile beacon simulation

The simulation of mobile beacon is similar to DV-hop algorithm. The distributed unknown node is 20. Choose the number of randomly deployed

Table 4.2 Average position errors and traffic of the Mobile beacon

No. of beacons	Average traffic	Error Interval
3	19.07	4.0153
4	28.27	1.9061
5	35.11	2.1342
6	44.21	1.0012
7	61.23	0.9105
8	67.11	1.0623
9	69.05	1.520
10	73.90	1.6424

beacons as the independent variable and its range is from 3 to 10. Then simulation result of mobile beacon is show in Table 4.2. The computed algorithm shows that the values are different from the actual values. If the value of the node is different then the position of the node would be completely different. The result also shows that there are many errors in this evaluation. These errors will affect the accuracy of the algorithm.

4.3 Composite approach simulation

The DV-hop performance depends on the network topology to a great extent [21]. The setting is illustrated in table 4.3. Because of the trajectory of the mobile beacon is in Figure 2.2, when the mobile beacon finishes the traversing the whole region, all the beacon will form a relative isotropic topology. The regular placements of the beacons reduce the errors effects on the algorithm performance. Seven homogeneous distributor beacons are used for the DV-hop. The unknown nodes are randomly increasing from the 20 to 100 at the simulation area.

Table 4.3 Average position error and traffic of composite approach

No. of beacon	**Average traffic**	**Error interval**
3	20	0.29
4	40	0.31
5	60	0.35
6	80	0.33

4.4 Enhanced composite approach with mobile beacon shortest path simulation

Mobile beacon traverse the deployment area with the shortest path. Deployment area is partitioned into hexagon cells as in cellular network. The mobile beacon passes at the mid point of each hexagon cell to follow by any traveling salesperson algorithm for shortest path. The main goal of this approach is to

reduce the power, required for computation and traversing. When mobile beacon traverse the shortest path to cover the deployment region definitely it saves the power. Further this method is cost saving as it required only one GPS which is inbuilt or physically added in mobile beacon to cover the shortest path. The deployment area is divided into hexagon cells and mobile beacon trajectory follow the shortest path, moving center of each hexagon cells reduce the little bit error in comparison of composite approach. Average traffic not affected by mobile beacon shortest path so it almost equal to the previous composite approach. So this method improves a little bit performance and efficiency. We can see improved mobile beacon trajectory with shortest path in figure 2.3.

Table 4.4 Average position error and traffic of enhanced composite approach

No. of beacon	**Averag e traffic**	**Error intervals**
3	20	0.27
4	40	0.29
5	60	0.33
6	80	0.31

When we compare the result of average traffic and error intervals with other approaches then we find the enhanced composite approach with mobile beacon shortest path is a bit better then composite approach. But this approach will give much better result in terms of power saving which reduces the cost also, as compared the other approaches. When the deployment area is large then this algorithm plays an important role as it consumes less power. So this algorithm is good for battlefield surveillances, Industrial and large geographical applications.

Chapter 5
CONCLUSION & FUTURE WORK

This proposed method provides high localization precisions, low payload of the traffic and high self adaptability. However, the requirement of the beacon is exigent and rigid. When the dimension of the wireless sensor network is very big, energy depletion leads the infectivity of the mobile beacon. We have developed an optimal movement schedule for mobile beacon that can achieve a shortest path under expected localization accuracy using cellular hexagon cells.

Algorithms show that there are some merits and demerits of all the algorithms. Some localization schemes have fewer merits and greater demerits and some of them have less demerits and greater merits. These merits and demerits were the main source for proposing the idea of a unique approach which is the enhanced composite approach. The proposed algorithm may address those problems which are faced by company in real time deployment. Definitely the results of the approach show worth of the localization schemes. It shows the use of an algorithm, and it is very important to know about the usage of an algorithm.

Localization problem is an open challenge in wireless sensor network. There are many aspects where we need improvements such as how to define threshold value in wireless sensor network. Security is another aspects, as the data is transferred from mobile beacon node to blind node then any of mobile beacon which is a virus or not secure acting as original mobile beacon transmit false message, Due to that an error will occur which is harmful for our computation. Environmental obstacles like indoors, walls, cage, mountains etc are some issues which comes when we do measurements in real deployment area. So localization system should be able to overcome these problems.

In future work, we would like to modify this approach to make the already position aware static nodes to participate in localization. Also the consideration of changing communication range for the mobile nodes is seen as a potential area for future work in three dimensional.

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LIST OF RESEARCH PAPERS PUBLISHED

Paper1-

Sunil Kumar, Niraj Singhal, Kapil Tomar, (Dec 2010), "An enhanced composite approach with mobile beacon shortest path to solve localization problem in wireless sensor network" published in International Journal of Engineering Science and Technology (IJEST) Vol. 2(12), 2010, 7579-7585. ISSN No. 0975-5462.

Paper 2-

Sunil Kumar, Niraj Singhal, "Mobile beacon with global positioning system to solve localization problem in three dimensional" accepted in International Journal of Engineering Technology and Science (IJETS).